УДК 633.11:631.53

DOI 10.22314/2073-7599-2018-12-4-22-28

Pre-sowing Treatment of Sunflower, Soybean and Maize Seeds with Low-Frequency Electromagnetic Radiation

Nelly S. Levina,
senior expert;
Yulia V. Tertyshnaya,
PhD(Chem), senior researcher,
e-mail: moraxella@bk.ru;

Irina A. Bidey,
laboratory assistant-research engineer;
Olga V. Elizarova,
laboratory assistant-research engineer

Federal Scientific Agroengineering Center VIM, Moscow, Russian Federation

Abstract. Pre-sowing seed treatment by various energy methods is used as an effective way of stimulating the seed material. (Research purpose) The authors have studied the effect of a low-frequency electromagnetic field on the seed properties of sunflower (Helianthus), soybean (Glycine max) and maize (Zea mays L.) seeds. (Materials and methods) Parameters of the electromagnetic field: induction of 16 mT, pulse repetition rate of 16 Hertz I; exposure time of 15 and 20 minutes. The experiment has been conducted in two stages. The first stage is the determination of the germination and germination energy of irradiated and non-irradiated seeds, as well as the biometric characteristics of seedlings: the mass of stems and leaves, the length and mass of the root system. The second stage is the phenological observations of the growth and development of plants according to the phases of their development in the VIM climatic chamber. (Results and discussion) It has been shown that the sowing qualities of maize seeds after 15 min of irradiation are higher than the control ones. It has been determined that germination energy has increased by 10 percent as compared to the control sample, germination by 8 percent, seedling weight by 6.4 percent, weight of stems and leaves by 16, root system by 3.4 and stem height by 30 percent. It has been found that there is no influence of low-frequency electromagnetic radiation on the germination of soybeans both in the laboratory and in the climate chamber. It has been found that at the end of the growing season, the mass of plants irradiated for 20 minutes has turned out to be greater than the control values by 20%, the root mass by 25%, and the root length by 16%. The authors have determined that the treatment of sunflower seeds (Helianthus) with a low-frequency electromagnetic field has no stimulating effect on germination energy and germination capacity, but contributes to an increase in the mass of plants when they are grown in a phytotron. It has been calculated that a 15-minute irradiation of sunflower seeds before sowing resulted in an increase in the mass of plants by 34.9%; the mass of the root system – by 22%; length of roots – by 3.65%; the head (anthodium) diameter – by 5.3% and their weights – by 25.3 %. (Conclusions) The response of plants to the energy impact depends on the type of crop. It has been determined that low-frequency magnetic radiation without changing the sowing properties of seeds can positively influence the growth and development of plants.

Keywords: sunflower seeds, soybean and corn seeds, germination energy, germination, low-frequency electromagnetic radiation, biometric indicators.

For citation: Levina N.S., Tertyshnaya Yu.V., Bidey I.A., Elizarova O.V. Pre-sowing treatment of sunflower, soybean and maize seeds with low-frequency electromagnetic radiation. *Selskokhozaistvennye mashiny i tekhnologii*. 2018. 12(4): 22-28. DOI 10.22314/2073-7599-2018-12-4-22-28. (In Russian).

Improving the quality of seed material and, as a reasult, increasing yields is the most important task of Russian farm industry. For many years, new methods and technologies for cultivating, processing and preserving crops have been developed [1-3].

Since during the storage of seeds, their bioenergetic capacity is depleted, it is recommended to use various energy effects for effective awakening of seed material, healthy growth and development of plants [4-6].

In recent years, the intensification of crop production in farm practices began to actively introduce electrophysical methods of affecting plants and seeds of cereals, vegetables, and legumes [7, 8]. There are physical methods of influencing the seed material, such as the electromagnetic field of various ranges, γ-radiation, ultraviolet, infrared, laser radiation, electric field of the corona discharge, and ultrasonic effect [9, 10]. In many works their effect on the improvement of the sowing qualities of cereals and vegetable crops is shown, as well as an increase in the preservation of the yield of fruit-bearing crops [11, 12]. Despite the positive results of the exposure to various types of radiation and long-term studies in this field, there is no unequivocal opinion on this matter. Several mechanisms of action

are proposed: the stress response of the system, the effect on photosynthetic activity and the porphyrin response, and the change in the water structure.

The present work discusses the study results on the influence of an effective method of irradiation - low-frequency electromagnetic field. The value of the work is grounded by the complex study of the sowing qualities of maize, soybean and sunflower seeds both in laboratory conditions and phenological observations in the phytotron.

The research purpose is to determine the sowing properties of sunflower (*Helianthus*), soybean (*Glycine max*) and maize (*Zea mays L.*), as well as biometric parameters of plant morphological organs after their exposure to low-frequency electromagnetic radiation.

Materials and methods. For the experimental purpose, selection material included the seeds of soybean variety «Slavia», a maize hybrid «Krasnodar 291-AMV» developed by Krasnodar Research Institute for Agriculture named after P.P. Lukyanenko, and sunflower variety «Dobrynya». The seeds were exposed to a low-frequency electromagnetic field with an induction of 16 mT and a pulse repetition rate of 16 Hz for 15 and 20 min.

Non-irradiated seed samples were used as control ones. Seed processing was carried out two weeks before the beginning of experimental studies to assess the effect of low-frequency electromagnetic radiation on planting properties, growth and the development of plants.

The studies were carried out in two stages. At the first stage, the researchers evaluated the viability and germination of irradiated and non-irradiated seeds, as well as the biometric characteristics of seedlings: the mass of stems and leaves, the length and mass of the root system.

The second stage included phenological observations of the growth and development of plants in their development phases in the VIM climatic chamber. In the chamber there were installed containers of 40 60 45 mm filled with soil. During the vegetation of plants in the climatic chamber daily observations were made of their growth and development.

Sowing parameters of the seeds were determined in accordance with the methodology set out in GOST 12038-84. Germination of seeds of large-seed crops (soybean, corn, sunflower), was carried out in the propagators filled with moistened sand. The number of seeds in the sample was 50 pieces, with four replicates. Seed viability was determined on the 5th day, germination – on the 8th day after sowing. Biometric indicators of seedlings (germination phase) were determined in 10 plants, in the harvesting phase – for all remaining plants.

At the end of the vegetation period, the plants were carefully removed from the containers along with the root system and their heights, masses of the aerial parts of plants and root systems were measured.

The tables show the arithmetic mean values of the indicators. The relative error did not exceed 3%.

Results and discussion. Corn. The results of laboratory studies on the evaluation of the influence of a low-frequency electromagnetic field on the sowing properties of the seeds of the maize hybrid «Krasnodar 291-AMV» and biometric indices of seedlings are given in *Tab. 1.*

Table 1

The response of biosystems of maize seeds and their seedlings to the effect of electromagnetic radiation

Controlled parameter	Time of irradiation of seeds (τ), min		
	0 (Control)	15	20
Energy germinations, %	85,0	95,0	95,0
Germination, %	90,0	98,0	100,0
Weight of seedling, g	1,266	1,347	1,181
Green mass, g	0,308	0,357	0,290
Mass of roots, g	0,958	0,991	0,891
Height of plants, sm	9,8	12,85	11,35
Dry content in the seedling, %	86,29	86,93	86,82

The analysis of the data obtained showed that pre-sowing treatment of maize seeds with a low-frequency electromagnetic field for 15 and 20 min had a positive effect on the process of yielding seeds from the state of rest. The values of seed viability and germination of maize seeds during their treatment for 15 and 20 min. increased by 10% as compared with the control values.

The highest seedling weight, its green mass (stem and leaves), the root system, and the dry matter content were obtained by treating the seeds for 15 minutes. Increasing pre-sowing effect time on corn seeds up to 20 min led to a significant decrease in biometric indicators of seedlings as compared with the control samples.

At the second stage, the effect of a low-frequency electromagnetic field on the growth and development of maize plants in a climatic chamber was evaluated.

During corn vegetation in the climatic chamber, daily observations were made of the growth and development of plants (*Fig. 1*). The first seedlings appeared in 8 days after sowing.

At the end of the vegetation period, measurements were taken of the height and weight of plants with a root system; the mass of the aboveground part of the plants, and the length and mass of the roots.

Biometric indices of plants grown from seeds irradiated with a low-frequency electromagnetic field within 15 minutes were significantly higher than similar


Fig. 1. The process of growing maize plants (Zea mays L) in the VIM climatic chamber

data obtained with a 20-minute irradiation. The height of the aerial part of the plants was 4% higher than the control value, the weight of the aerial part – by 8.8%, the length of the roots – by 17.2% and the mass of the roots by 13.6%.

Table 2

BIOMETRIC INDICATORS OF MORPHOLOGICAL ORGANS MAIZE PLANTS GROWN IN A CLIMATIC CHAMBER

Controlled parameter	Time of irradiation of seeds (τ), min		
	0 (Control)	15	20
Height of the aerial part plants, sm	78,33	81,46	74,66
Mass of the aerial part plants, g	18,47	20,09	14,31
Length of the roots, sm	17,55	20,56	14,44
Mass of the roots, g	0,66	0,75	0,57

Biometric indices of plants grown from seeds irradiated with a low-frequency electromagnetic field within 15 minutes were significantly higher than similar data obtained with a 20-minute irradiation. The height of the aerial part of the plants was 4% higher than the control value, the weight of the aerial part – by 8.8%, the length of the roots – by 17.2% and the mass of the roots by 13.6%.

Sunflower. Analysis of the data obtained under laboratory conditions showed that the treatment of the seeds for 15 and 20 min. had no stimulating effect on their seed germination and the biometric characteristics of seedlings (*Tab. 3*). Thus, in seeds irradiated for 15 min. a decrease in germination by 10% was observed, in case of a 20-min. treatment, the seed germination was practically unchanged as compared to the control values. When the seeds are irradiated for 15 min., the magnitude of the deviation of the controlled parameters from the control values was slightly lower as compared with similar data obtained with a 20-minute seed irradiation.

A comparison of the morphological characteristics

Table 3

SOWING PROPERTIES OF SEEDS AND BIOMETRIC INDICATORS OF SEEDLINGS AND SUNFLOWER PLANTS

Controlled parameter	Time of irradiation of seeds (τ), min		
	0 (Control)	15	20
The phase of germination (laboratory conditions)			
Germination energy, %	63,0	65,0	70,0
Germination, %	95,0	85,0	95,0
Weight of seedling, g	1,483	1,423	1,357
Mass of the aerial part plants, g	0,977	1,049	1,026
Mass of the root, g	0,513	0,374	0,331
Height of a plant, sm	9,8	12,85	11,35
Dry content in the seedling, %	81,76	81,84	82,13
Harvesting phase (climate chamber)			
Weight of a plant, g	28,05	37,83	31,15
Height of a plant, sm	108,5	108,33	114,67
Mass of the root, g	2,11	2,58	2,26
Length of the root, sm	11,5	11,92	13,17
Diameter of flower heads, sm	5,08	5,35	6,34
Weight of flower heads, sm	16,61	20,85	15,07

of the plant parts obtained from the treated seeds with the control samples showed that a 15-minute irradiation of the seeds before sowing resulted in an increase in

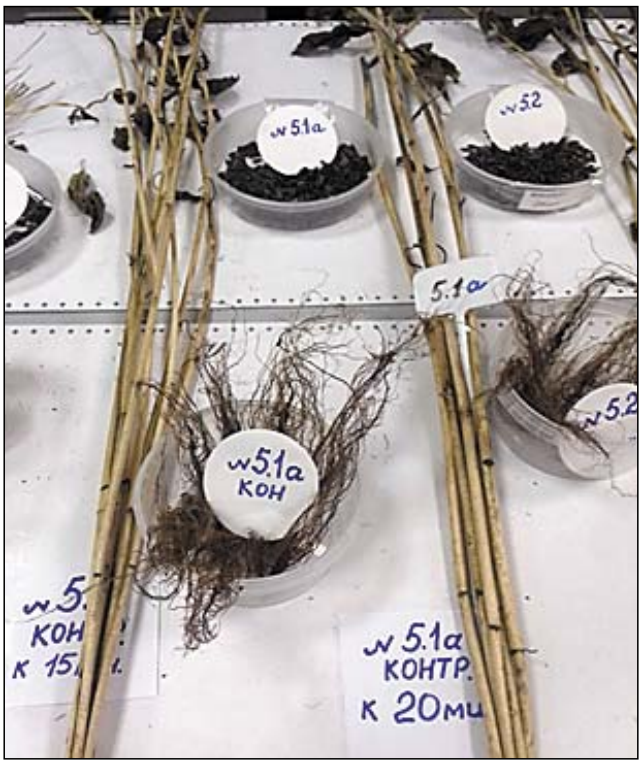

Fig. 2. Morphological parts of sunflower plants and seeds after harvesting

the mass of plants by 34.9%, the root system weight by 22%, the root length by 3.65%, the head (anthodium) diameter – by 5.3% and their weight – by 25.3% (*Fig. 2, Tab. 3*). Biometric indicators of plant parts grown from seeds irradiated for 20 min. were significantly lower than the control samples. It should be noted that seeds in the heads of all harvested plants were immature.

Thus, the treatment with a low-frequency electromagnetic field for 15 minutes was the preferred method for sunflower seeds of the «Dobrynya» variety.

Soybeans. «Slavia» is a highly productive early soybean variety for grain producion, with a vegetation period of 95-105 days. The average weight of 1000 seeds is 172 g. The seeds accumulate up to 42% protein and up to 23% oil.

The viability of soybean seeds is determined in laboratory conditions, their germination in laboratory conditions and in a climatic chamber (*Tab. 4*).

Table 4

DETERMINATION OF SOWING INDICATORS OF SOYBEAN SEEDS VARIETIES «SLAVIA»

Conditions cultivations	Characteristic	Time of irradiation of seeds (τ), min		
		0 (Control)	15	20
Petri dish	Germination energy, %	95	85	88
	Germination, %	95	92	95
Climatic chamber	Germination, %	85	70	75

As a result of seed treatment, the aforementioned electromagnetic field has reduced their sowing indices, both in the laboratory and in the climatic chamber. The energy of seed germination when irradiated for 15 min. as compared to the control samples decreased by 10%, germination – by 3%. With a 20-minute irradiation, the laboratory energy of seed germination decreased by 7%. Germination of seeds in the climate chamber decreased by 15 and 10%, respectively.

Nevertheless, a positive trend of the influence of irradiation with an electromagnetic field was observed during the growth of soybean in the phytotron. A gradual increase was noticed in the aboveground mass of plants according to the variants of the experiment, the development of the root system, the intensity of flowering and fruit formation. However, externally, plants formed from seeds irradiated for 15 min., were slightly lower in height than the control samples and plants with 20-minute irradiation.

As a result of low-quality electromagnetic influence on soybean seeds, the biometric parameters of seed plants have changed, as well as qualitative indicators obtained after the growing season (*Tab. 5*)

Table 5

BIOMETRIC INDICATORS OF MORPHOLOGICAL ORGANS OF SOYBEAN PLANTS UNDER DIFFERENT IRRADIATION REGIMES

Controlled parameter	Time of irradiation of seeds (τ), min		
	0 (Control)	15	20
Weight of a plant, g	2,33	2,89	2,80
Mass of the aerial part plants, g	1,81	2,26	2,15
Mass of root, g	0,52	0,63	0,65
Height of a plant, sm	49,1	44,5	57,7
Height of a stem, sm	33,2	29,7	39,3
Length of a root, sm	15,85	14,8	18,4
The mass of 1000 seeds', g	153,0	166,0	164,0
Thickness of the stem, mm	2,06	2,06	2,17

An increase in the weight of plants and the mass of 100 seeds was observed both at 15 and at 20 minutes of low-frequency electromagnetic action, and at $\tau = 15$ min this index was higher. However, the remaining indices were significantly lower than those after irradiation, $\tau = 20$ min. After 20 minutes of irradiation, the root system of the plants was more developed featuring the longer root length and mass.

CONCLUSIONS

1. Pre-sowing treatment of maize seeds with low-quality electromagnetic radiation had an ambiguous effect on their sowing qualities and the formation of plants grown from them. Irradiation of seeds for 15 min. led to an increase in germination energy as compared to the control values by 10%, germination – 8%, seedling mass – 6.4%, stems and leaves - 16%, root system – 3.4%, stem height – 30%. At 20-minute seed irradiation, although there was some increase in germination (10%), however, the biometric indices of seedlings obtained in laboratory conditions and plants grown under phytotron conditions were lower as compared with the control samples.

2. Low-frequency electromagnetic radiation did not have a stimulating effect on the soybean's sowing quality, 20 minutes of seed irradiation led to an increase in the mass of plants at the end of the growing season by 20%, the root mass by 25%, and their length by 16%.

3. The exposure of sunflower seeds to a low-frequency electromagnetic field did not have a stimulating effect on seed viability and germination, but yielded a positive

result in the harvesting phase of plants. A comparison of the morphological characteristics of plant parts obtained from irradiated seeds and grown under the phytotron conditions with control indices showed that a 15-minute irradiation of the seeds before sowing resulted in an increase in the mass of plants by 34.9%; the mass of the root system – by 22 %; the length of roots – by 3.6%5; the head (anthodium) diameter – by 5.3% and their weight – by 25.3%; biometric indicators of plant parts grown from seeds irradiated for 20 minutes were significantly lower than those of the control values.

REFERENCES

1. Lachuga Yu.F., Izmaylov A.Yu., Zyulin A.N. Razrabotka i vnedreniye vysokoeffektivnykh, resurso- i energosberegayushchikh tekhnologiy i tekhnicheskikh sredstv posleuborochnoy obrabotki zerna i podgotovki semyan [Development and introduction of highly effective, resource and energy-saving technologies and technical means of post-harvest grain processing and seed preparation] // *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2009. N1: 2-9. (In Russian)

2. Yakushev V.P., Mikhailenko I.M., Dragavtsev V.A. Reserves of agrotechnologies and breeding for cereal yield increasing in the Russian Federation // *Agricultural Biology*. 2015. 50: N5: 550-560. (In English)

3. Izmaylov A. Yu., Evtushenko N. E., Kurbanov R. K. Modernizatsiya tekhnologiy transportirovaniya selektsionnogo urozhaya [Modernization of technologies for transporting harvested selection crops] // *Vestnik sel'skokhozyaystvennoy nauki*. 2017. N2: 6-8. (In Russian)

4. Pavlov S. A., Dadyco A. N. Osobennosti syshki zerna pri ispolzovanii topochnyh blokov na tverdom toplive [Features of grain drying when using combustion blocks on solid fuel] // *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2017. N4: 9-13. (In Russian)

5. Tertyshnaya Yu. V., Levina N. S., Elizarova O. V. Vozdeystvie ultrafioletovogo izlucheniya na vshozhest' I rostovie protsessy semyan pshenitsy [Influence of ultraviolet radiation on the germination and growth processes of wheat seeds] // *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2016. N5: 24-29. (In Russian)

6. Tertyshnaya Yu.V., Levina N.S. Vliyanie spektralnogo sostava sveta na razvitie selskokhozyaystvennyh kultur [Influence of spectral composition of light on the development of farm crops] // *Sel'skokhozyaystvennye mashiny i tekhnologii*. 2016. N5: 24-29. (In Russian)

7. Kutyrov A.I., Khort D.O., Filippov R.A., Tsench Yr.S. Magnitno-impul'snaya obrabotka semyan zemlyaniki sadovoy [Magnetic-pulse treatment of strawberry seeds] // *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2017. N5: 9-15. (In Russian)

8. Rakosy-Tican L., Aurori C.M., Morariu V.V. Influence of near null magnetic field on in vitro growth of potato and wild Solanum species. // Bioelectromagnetics. 2005. 26: 548-557. (In English)

9. Sahebjamei H., Abdolmaleki P., Ghanati F. Effects of magnetic field on the antioxidant enzyme activities of suspension-cultured tobacco cells // Bioelectromagnetics. 2007. 24: 42-47. (In English)

10. Abdolmaleki P., Ghanati F., Sahebjamei H., Sarvestani A.S. Peroxidase activity, lignification and promotion of cell death in tobacco cells exposed to static magnetic field // *Environmentalist*. 2007. 27: 435-440. (In English)

11. Egorova I. V., Kondratenko E. P., Soboleva O. M., Verbitskaya N. B. Vliyanie obrabotok zerna pshenitsy elektromagnitnym polem na soderzhanie vodorastvorimyh vitaminov [Influence of wheat grain processing with an electromagnetic field on the content of water-soluble vitamins] // *Razionalnoe pitanie, pischevie dobavki I biostimulyatory*. 2014. N1: 22-23. (In Russian)

12. Hirota N., Nakagawa J., Koichi K. Effects of a magnetic field on the germination of Plants. J. Appl. Phys. 1999. 85: 5717-5719. (In English)

13. Levina N.S., Tertyshnaya Yu.V., Bidey I.A., Yelizarova O.V., Shibryayeva L.S. Posevnyye kachestva semyan myagkoy yarovoy pshenitsy (Triticum aestivum L.) pri raznykh rezhimakh vozdeystviya nizkochastotnym magnitnym polem [Sowing qualities of seeds of soft spring wheat (Triticum aestivum L.) under different exposure modes to a low-frequency magnetic field] // *Sel'skokhozyaystvennaya biologiya*. 2017. 52: N3: 580-587. (In Russian)

14. Syrovatka V.I., Ivanov Yu.A., Kononov V.P., Popov V.D. Rekomendatsii po zagotovke i ispol'zovaniyu vysokovlazhnogo furazhnogo zerna [Recommendations on harvesting and use of high-moisture feed grain]. Moscow: Rossel'khozakademiya, 2006. 130. (In Russian)

15. Alicamanoglu S., Sen A. Stimulation of growth and some biochemical parameters by magnetic field in wheat (Triticum aestivum L.) tissue cultures. // *Afr. J. Biotechn*. 2011. 53: 10957-10963. (In English)

The paper was submitted to the Editorial Office on 27.04.2018

The paper was accepted for publication on 07.06.2018

Conflict of interest.
The authors declare no conflict of interest.